# SMALL TRASH IDENTIFICATION IN COTTON USING IMAGING TECHNIQUES

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## Abstract

This paper discusses the identification of small trash objects in cotton using machine vision-based systems. Twenty-one lots of cotton from three growing regions were harvested and processed to test the suitability for high performance spinning. Trash objects were categorized into various size categories based on the equivalent diameter of the objects. The trash distribution from the Cotton Trash Identification System developed at the Southwestern Cotton Ginning Research Laboratory was compared to AFIS and HVI measurements. The machine vision-based systems can evaluate cotton trash, dust, and total counts and were compared to similar AFIS data. The CTIS system developed uses a high resolution camera and can identify objects of smaller size ($0.005 \text{ mm}^2$, 2 pixels) as compared to HVI Trashmeter software ($0.045 \text{ mm}^2$, 1 pixel). Categorization of trash objects in cotton, in real-time, allows for process control and could have a significant impact on the cotton industry.

## Introduction

Cotton grown in different areas vary in trash levels, each categorized based on certain trash types and sizes. This requires varying cleaning regimes. The types of trash and levels also depend on the harvesting techniques (machine picked or machine stripped). Current techniques that are available for the identification of trash in cotton include the Advanced Fiber Information System (AFIS), High Volume Instrumentation (HVI), and Shirley Analyzer. The Shirley Analyzer is a gravimetric measure that indicates the amount of total trash present in cotton samples without further differentiation. This paper presents a comparison of measurements from the Cotton Trash Identification System (CTIS) developed at the Southwestern Cotton Ginning Research Laboratory (SWCGRL) with measurements from AFIS and HVI.

Trash measurements from AFIS include the percent content of foreign matter or visible foreign matter (dust and trash). The measurement is by an optical sensor and categorizes the trash objects in terms of the equivalent diameter of the objects. All trash objects 50 to 500 µm are categorized as dust particles and all objects larger than 500 µm are categorized as trash. A histogram of the total number of objects in 50 µm increments along with the trash count and dust count per gram of cotton are available (Zellweger Uster®, Knoxville, TN).

HVI measurements provided by USDA-Agricultural Marketing Service (AMS) currently provide the percent trash area in raw cotton samples. However, no non-intrusive techniques exists that can be accurately used in the cotton industry to categorize the trash objects in raw cotton based on their size.

Advances in textile processing technology have substantially impacted the spinning industry. Rotor speeds of open- end spinning systems and vortex spinning systems have yielded significant increases in the spinning productivity for cotton processing. Studies conducted by Thibodeaux et al. (2003) examined the impact of fiber properties on the spinning process. This study further evaluates small trash particles found in raw cotton. Knowledge of this trash distribution could be used by the textile industry to improve processing. This trash distribution could predict ends down and other aspects which decreases a textile mills spinning efficiency.

## Materials and Methods

This research effort is collaborative work with Cotton Quality Research Station (CQRS), Clemson, SC, to examine the feasibility of small trash identification using imaging techniques. It comprises a preliminary study of the categorization of small trash objects found in cotton based on the size of the trash objects. Cottons tested in a study conducted by the Southern Research Regional Center, Agricultural Research Service, United States Department of Agriculture (SSRC-ARS-USDA) and the CQRS-ARS-USDA (Thibodeaux, et al., 2003) was used in this research effort. A total of 21 cottons with two sub samples were used.

The AFIS measurements consists of the histogram of trash distribution in terms of particle count in 50 μm increments up to 2000 microns and all trash objects = 2000 microns (equivalent diameter). In addition the trash count, dust count and total counts of the trash particles are included in the report. AFIS measurements include the average of 3 reps per sample.

Research currently being conducted at CQRS includes the categorization of trash objects based on the pixel area of the trash objects. A 900A HVI Trashmeter (Zellweger Uster®, Knoxville, TN) is currently used by the testing laboratory at CQRS. New HVI Trashmeter software developed for the HVI 900A system currently locates and categorizes the trash objects in terms of pixels (Foulk, 2003). The identified trash particles were then sorted into 25 categories based on their pixel size. The first 21 categories are in 5 pixel increments. For example, trash objects less than 5 pixels are in category 1, objects > 5 pixels and = 10 pixels in category 2 until category 20 (objects > 95 pixels and = 100 pixels). The next 5 categories are in 100 pixel increments, category 21 includes objects > 100 pixels and = 200 pixels till category 25 which includes all objects > 500 pixels. (Each pixel represents an area of approximately 0.045 mm$^2$.) . The HVI Trashmeter measurements include the average of 4 reps per sample.

In the CTIS, a total of up to 10 reps for each cotton lot were used to compute the number of trash objects in terms of pixels and equivalent diameter along with the trash count, dust count, and total count. If the total trash area (sum of areas of all trash objects in the image) of an image was within mean ± 3* standard deviations of the image set, the image was included in the image set.

CTIS is a vision-based system that acquires images using a RGB color camera and the Matrox® family series imaging boards that feature on-board, high-speed processing. The Matrox Imaging Library (MIL Ver. 7.5) image processing software, along with custom algorithms are used to process cotton images to identify trash. The acquired images were flat field corrected to remove spatial illumination non-uniformity (Lieberman and Patil, 1997). Trash pixels were separated from the cotton lint background (segmented) using a simple threshold on the intensity plane in HLS (Hue, Luma, Saturation) color space to obtain a binary image where each trash object is identified (Siddaiah, et al., 1999a,b, 2000, 2002a,b).

The CTIS acquires images of size 1280 x 1024 pixels (61 mm x 53 mm viewing area, 3233mm$^2$). The area of each pixel is 0.05 mm x 0.05 mm. The smallest trash object that can be identified by the imaging system is 2 pixels (0.005 mm$^2$). The HVI Trashmeter software currently used at CQRS acquired images of size 9 in$^2$ (5806 mm$^2$) with approximately 14,363 pixels in one square inch (Foulk, 2003). The area of each pixel is approximately 0.045 mm$^2$. Each pixel in the images acquired by the CTIS system is equivalent to 18 pixels (approximately) of the images acquired by the HVI Trashmeter. The CTIS can measure much smaller objects as compared to the HVI Trashmeter. The trash objects were categorized both in terms of pixel size and equivalent diameter (based on area measurements) and compared with HVI measurements and AFIS trash distribution. Figure 1 illustrates the steps involved in the categorization of the trash objects. Table 1 illustrates the image viewing area and the pixel sizes between the two systems.

The CTIS identifies the trash objects in cotton images and computes the area (*A*) of the trash objects in terms of pixels. AFIS reports trash distribution in terms of equivalent diameter in microns. HVI reports trash distribution in terms of pixels. In the CTIS, equivalent diameter of the trash objects are computed based on the area of the trash objects using,

$$\text{Equivalent diameter} = \sqrt{4*A/\pi}. \tag{1}$$

## Results and Discussion

Figures 2 and 3 illustrate two reps of the acquired cotton (Lot 5A) image and the segmented binary image with the trash objects identified. Figure 4 represents the trash distribution histogram (in pixels) from the CTIS and HVI trash measurements for cotton Lot 5A. HVI has been configured to locate and categorize trash particles into various size categories. But since the resolution of the CTIS is higher, it is able to separate trash particles into many smaller categories based upon pixel size. This is evident in Figure 4(b), where the categorization of trash objects in the HVI system of all objects < 5 pixels (enclosed in the ellipse) can further be categorized to approximately 18 smaller categories (enclosed in the ellipse) by the CTIS (Figure 4(a)). This further categorization could be useful to predict ends down problems during spinning due to the presence of certain size particles in high numbers. When comparing the histograms of the trash distribution by the two systems, it should be noted that the image viewing areas for the two systems are different as illustrated in Table 1. Please note that all images on the left side of the manuscript is referred as (a) and those on the right side are referred as (b).

Figure 5 represent the trash distribution histograms (in microns) from the CTIS and AFIS measurements. It can be observed that AFIS identifies more trash particles since it is a volumetric measure, in comparison to the CTIS categorization since only the surface of the cotton sample is analyzed. AFIS measurements are the average of 4 reps of 0.5 gram cotton samples as compare to an image viewing area 3230mm$^2$. Figures 6-9 illustrate the cotton images, and the trash distribution histograms

for Lot 13A cotton. These two lots (5A and 13A) were used to illustrate cottons with minimum and maximum amounts of trash in the sample set.

The correlation between CTIS and AFIS, trash count, dust count, and total count are illustrated in Figures 10, 11, and 12 respectively. Even though the correlation coefficients ($R^2$) are low, it should be noted that the various measurements are between a volumetric measure (AFIS) in comparison to surface trash measurement (CTIS). Figure 13 and 14 is the correlation between CTIS vs. HVI and HVI vs. AFIS total count measurements respectively. It can be seen that correlation between HVI vs. AFIS total count measures are higher than HVI vs. CTIS total count measures. Further research needs to be conducted to evaluate the reliability and repeatability of both the HVI and CTIS, and evaluate how close the trash count and dust count measurements track with AFIS measurements. The correlation between AFIS, HVI, and CTIS system are summarized in Table 2.

## Conclusion

The paper discusses the categorization of trash objects into size categories using CTIS, a machine-vision based system. The CTIS measurements are compared with HVI and AFIS measurements. The trash objects are categorized into various size categories based on the area of the trash objects in pixels and the equivalent diameter of the trash objects in microns. The smallest particle size the CTIS can identify is 0.005 mm$^2$ in comparison to the HVI Trashmeter which identifies particles of size is approximately 0.045 mm$^2$. The CTIS trash count, dust count, and total count are compared to AFIS measurements. Future research for on-line identification of trash objects to individual categories could be useful for the spinning industry for process control. The impact of such a system is wide ranging and could have significant benefits to the entire cotton industry.

## Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may be suitable.

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Table 1.  Pixel size of cotton images

|  | HVI Trashmeter | CTIS |
|---|---|---|
| Image Viewing Area | ˜ 5806 mm$^2$ (9 in$^2$) | ˜ 3230mm$^2$ (˜ 5 in$^2$) |
| Pixel (linear size) | ˜ 0.21 mm | ˜ 0.05 mm |
| Pixel (area) | ˜ 0.045 mm$^2$ | ˜ 0.0025 mm$^2$ |
| Number of Pixels | ˜ 1 | ˜ 18 |

Table 2.  Correlation coefficients of various parameters

| Measurements | Parameters | Correlation Coefficient ($R^2$) |
|---|---|---|
| CTIS vs. AFIS | Trash Count | 0.7205 |
| CTIS vs. AFIS | Dust Count | 0.7745 |
| CTIS vs. AFIS | Total Count | 0.7946 |
| CTIS vs. HVI | Total Count | 0.7991 |
| HVI vs. AFIS | Total Count | 0.8343 |
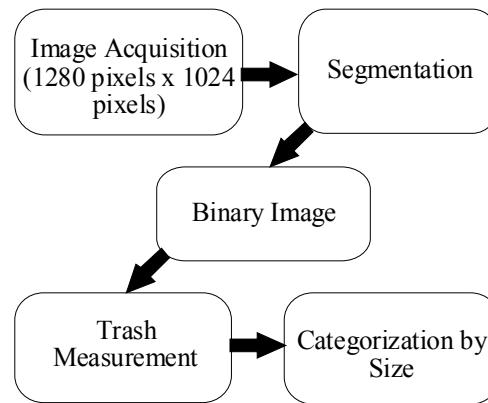


Figure 1.  Steps involved in categorization of trash.
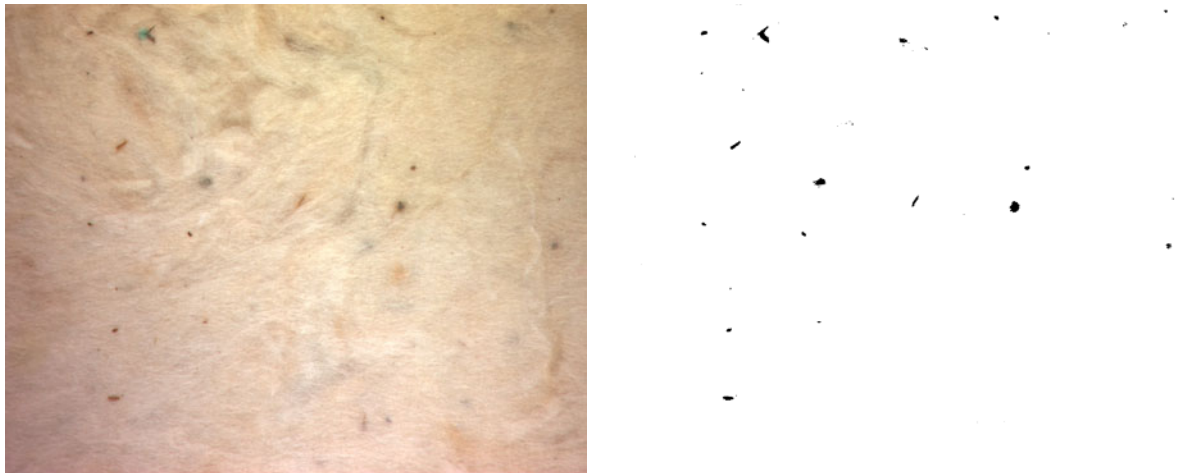


(Figure on the left is referred to as (a) and on the right referred to as (b) in the rest of the manuscript).

Figure 2.  Cotton image and the segmented binary image of MQ356 Lot 5A – Rep 1 (minimum trash content).

Figure 3.  Cotton image and the segmented binary image of MQ356 Lot 5A – Rep 9 (minimum trash content).
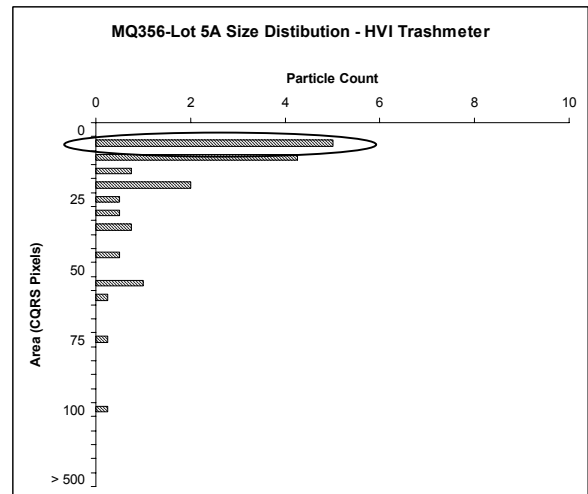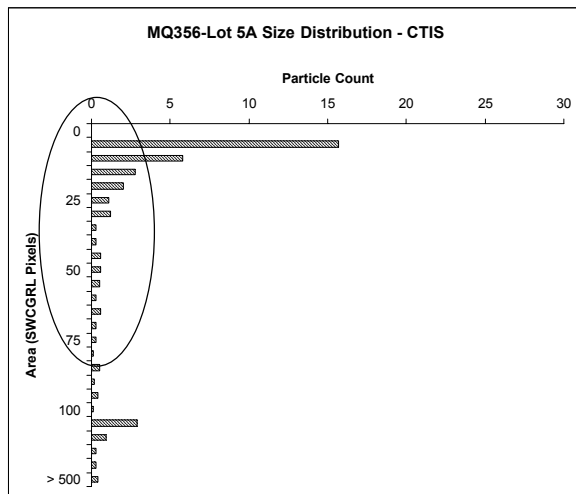


Figure 4.  CTIS and HVI trash distribution histogram of MQ356 Lot 5A (in terms of pixels).
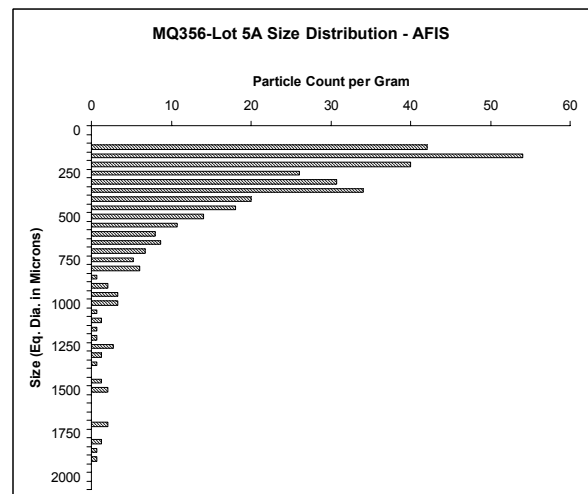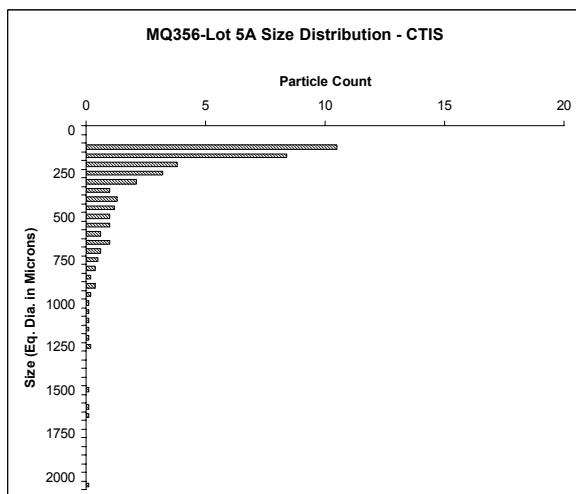


Figure 5.  CTIS and AFIS trash distribution histogram of MQ356 Lot 5A (in terms of microns).
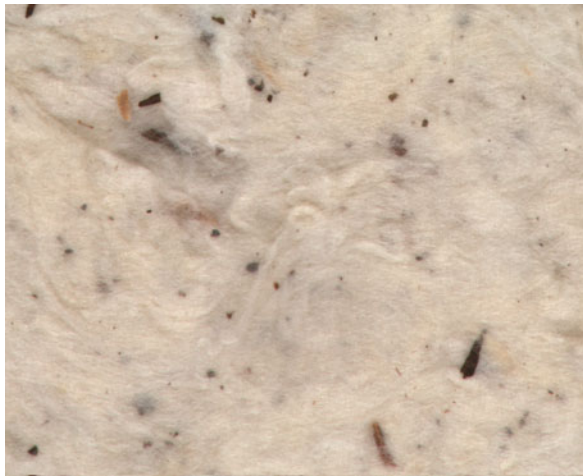
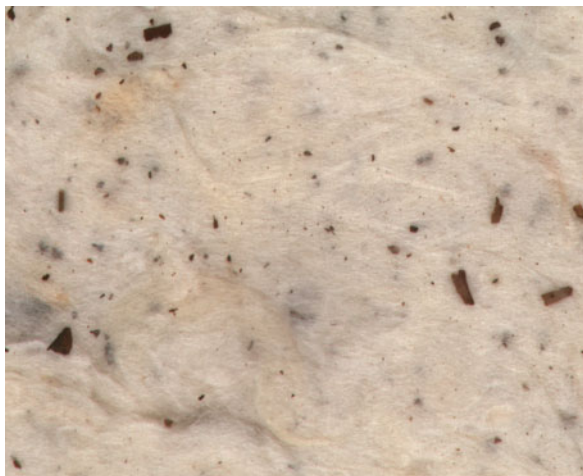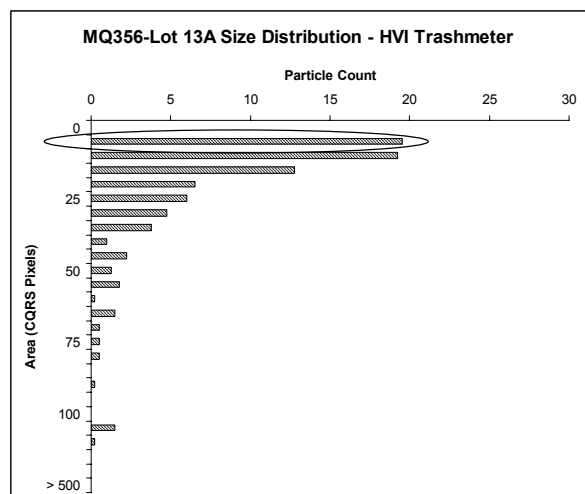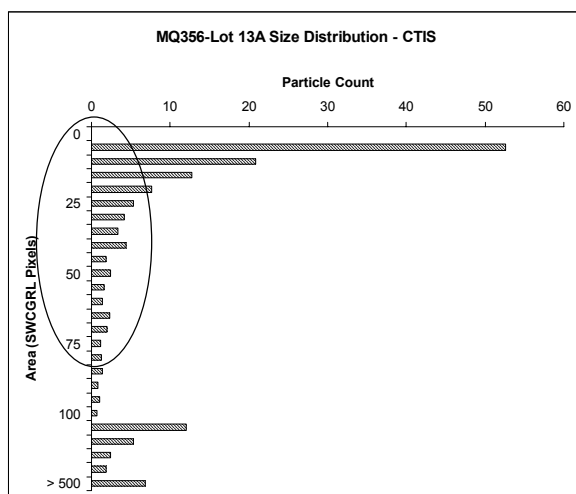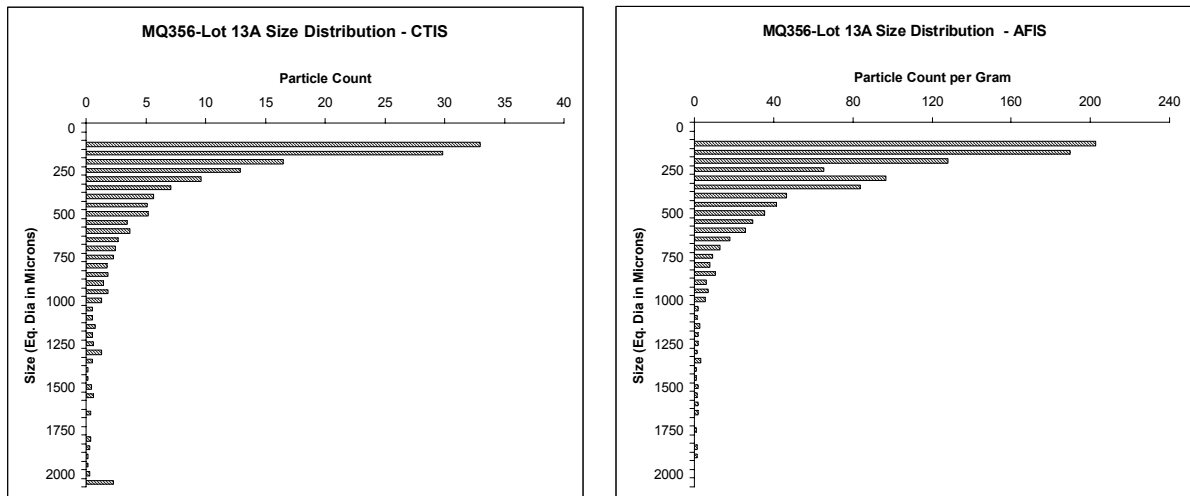Figure 6. Cotton image and the segmented binary image of MQ356 Lot 13A – Rep 1 (maximum trash content).



Figure 7. Cotton image and the segmented binary image of MQ356 Lot 13A – Rep 10 (maximum trash content).



Figure 8. CTIS and HVI trash distribution histogram of MQ356 Lot 13A (in terms of pixels).

Figure 9.  CTIS and AFIS trash distribution histogram of MQ356 Lot 13A (in terms of microns).
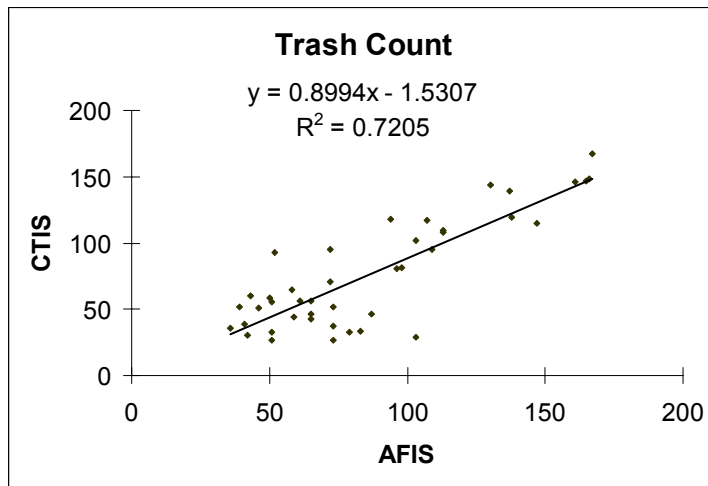

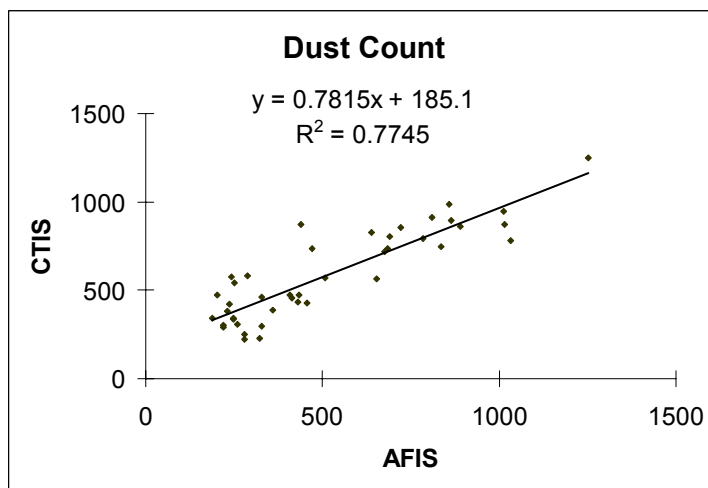
Figure 10.  Correlation between CTIS and AFIS trash count.



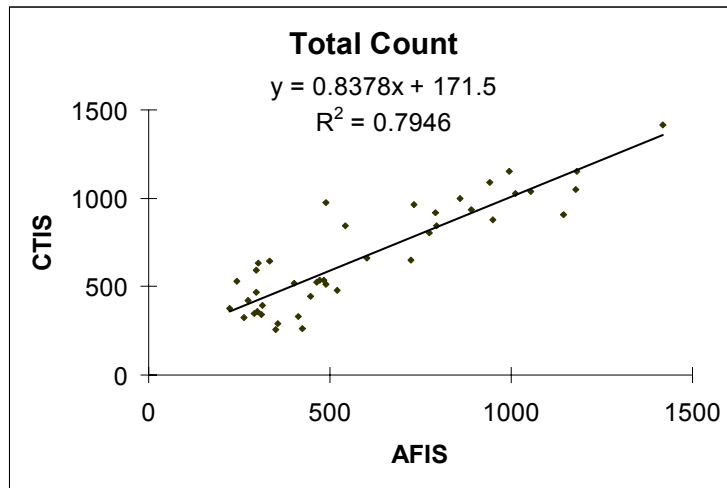Figure 11. Correlation between CTIS and AFIS dust count.

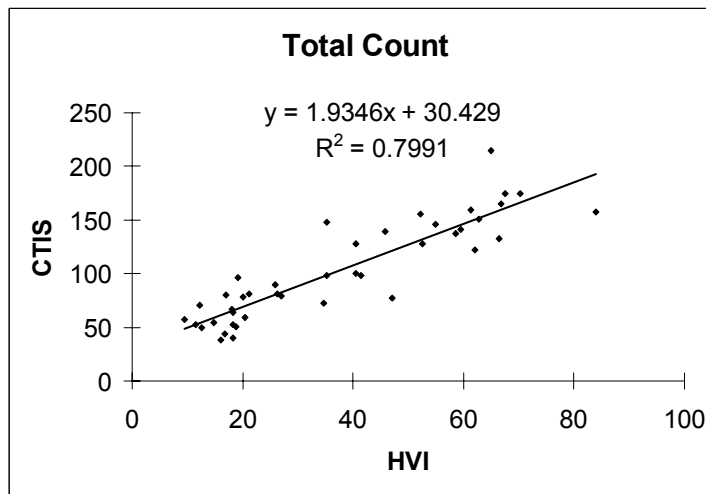Figure 12. Correlation between CTIS and AFIS total count.
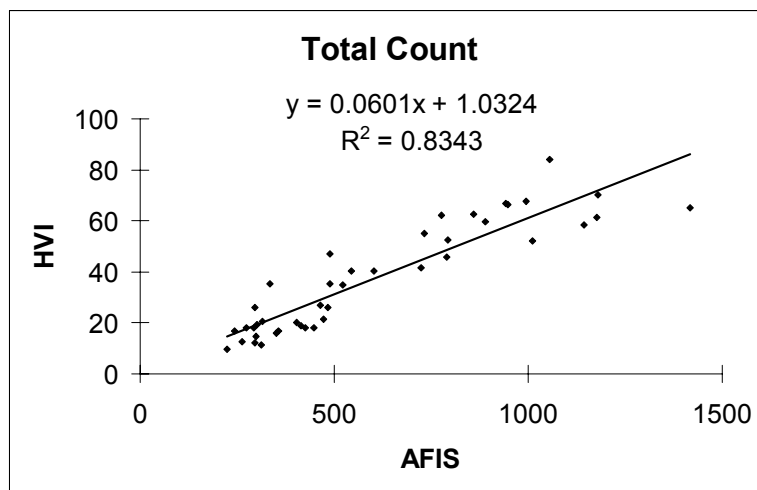


Figure 13. Correlation between CTIS and HVI total count.



Figure 14. Correlation between HVI and AFIS total count.